Human Exploration Development & Operations Office

Advancing Human Exploration & Discovery

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Science Off the Earth

An Integrated Approach to Science Operations in the Artemis Era and Beyond

Huntsville Operations Support Center (HOSC)

- Engineering and Science support since the earliest days of NASA
- Saturn V
- Skylab
- Space Shuttle & Spacelab
- International Space Station
- Supports over 4000 users from 14 different countries with telemetry, video, and voice services

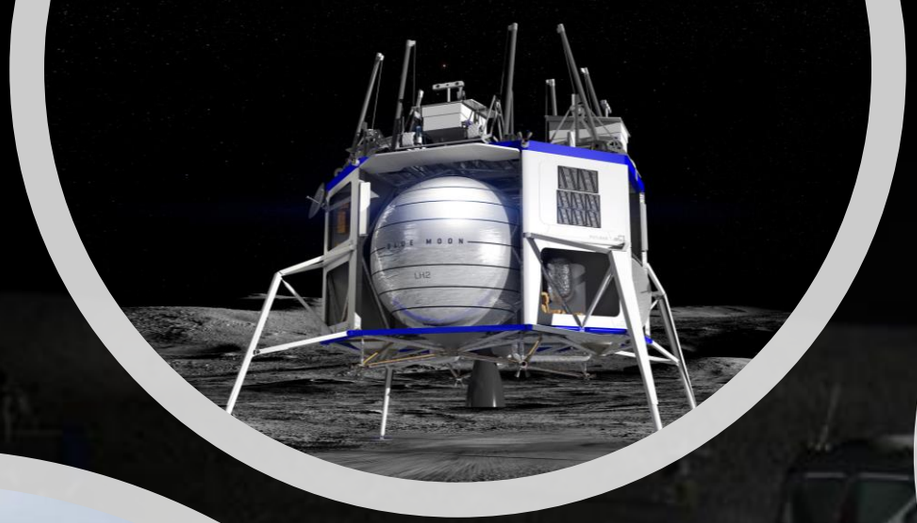
Payload Operations Integration Center (POIC)

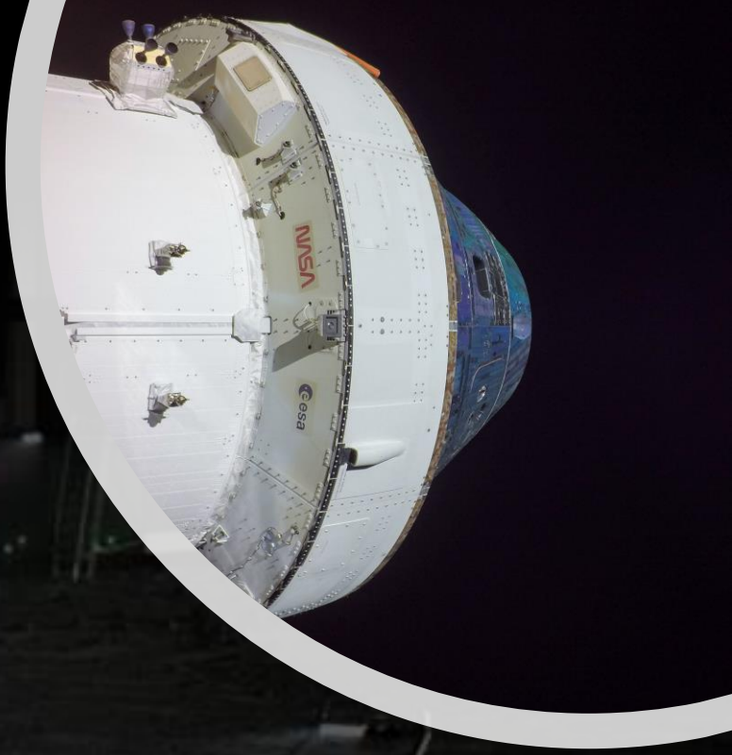
"Science Central"

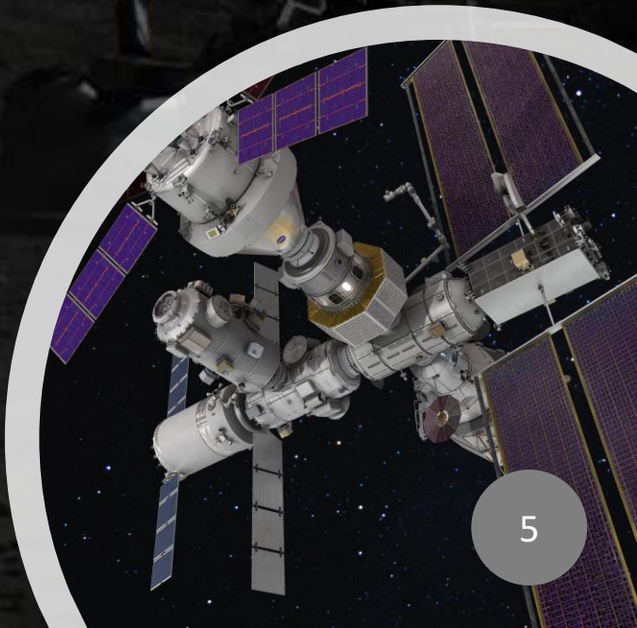
- Supporting ISS Science Ops 24x7 since 2001
- Responsible for all planning and operations of NASA payloads aboard ISS
- Integrate with nearly all NASA centers and many international researchers and operators
- Areas of Research
  - Biology & Biotechnology / Human Research / Physical Science / Earth & Space Science / Education / Technology
- ISS Assembly (1998-2012): 25 crew hours/week

Commercializing ISS

- Since 2012 over 40 Commercial resupply missions from SpaceX Dragon & Northrup Grumman Cygnus Resupply
- Commercial Crew Program increased the NASA/CSA/ESA/JAXA crew compliment from 3 to 4 crew starting in 2017
- Private Astronaut Missions
- New partners including UAE
- Typically 55-80 crew hours/week
- Significant increase and focus on ISS as a National Laboratory required innovative operational concepts







Artemis Elements

SLS – Orion – HLS – Gateway

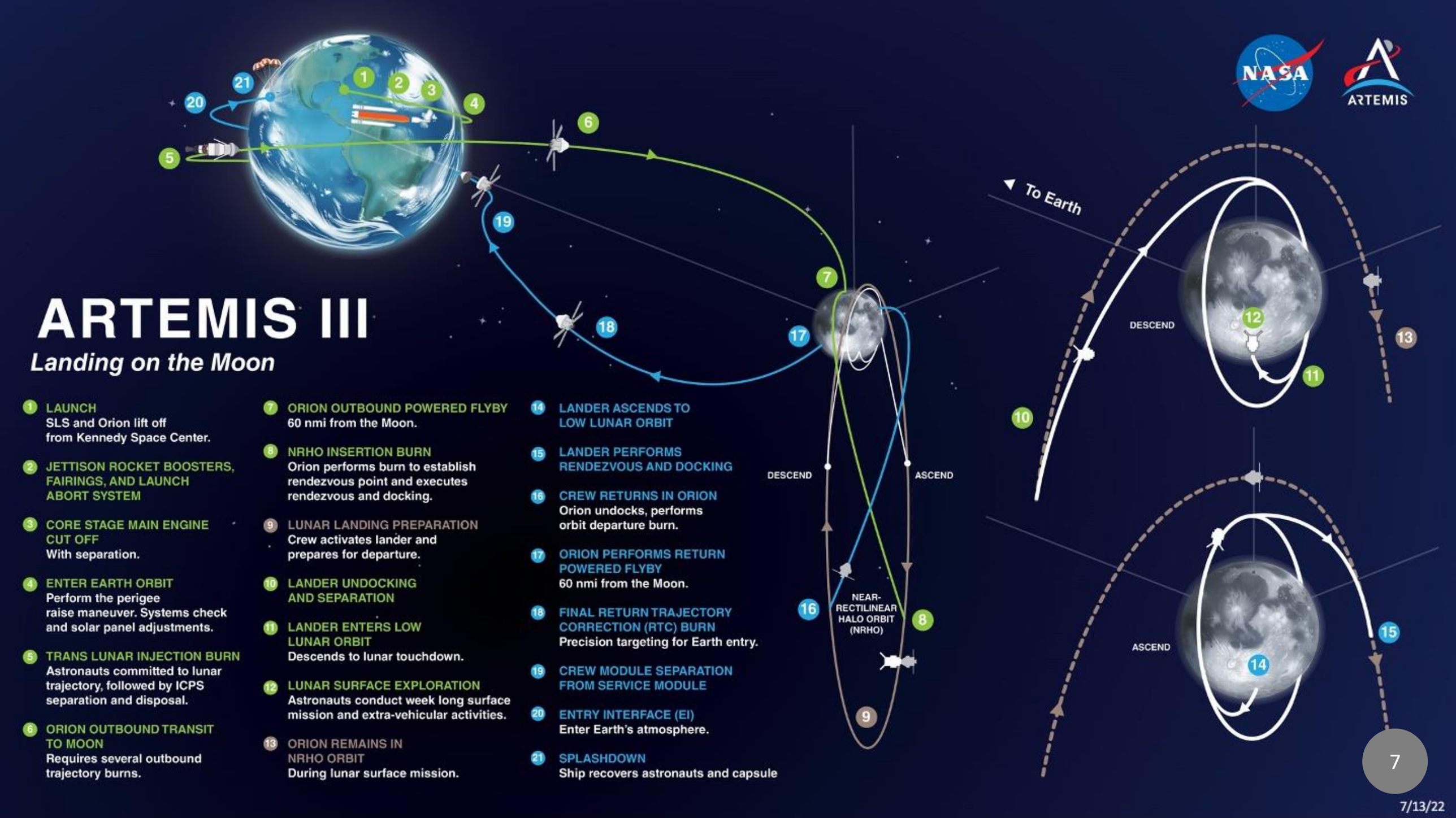
CLPS – Artemis Base Camp

ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

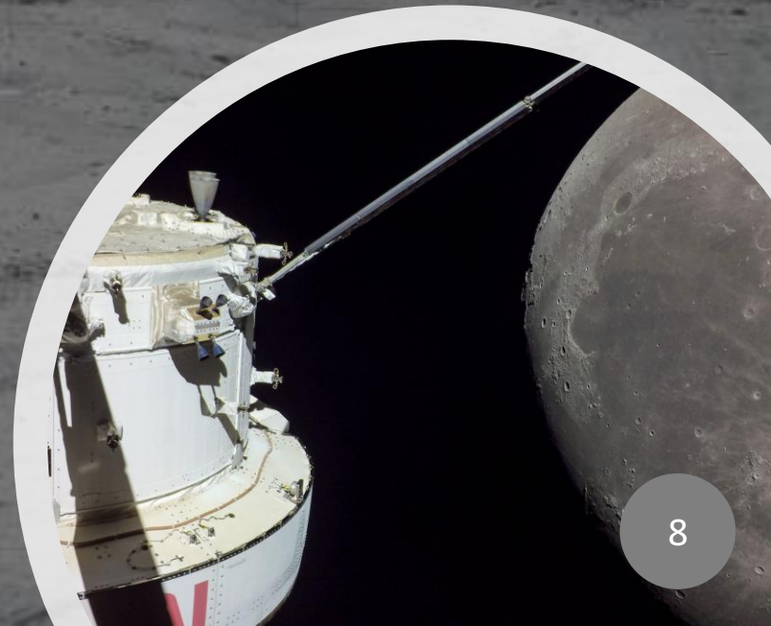
1. **LAUNCH**
   Astronauts lift off from pad 39B at Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **APOGEE RAISE BURN TO HIGH EARTH ORBIT**
   Begin 24 hour checkout of spacecraft.
6. **PROX OPS DEMONSTRATION**
   Orion proximity operations demonstration and manual handling qualities assessment for up to 2 hours.
7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) DISPOSAL BURN**
8. **HIGH EARTH ORBIT CHECKOUT**
   Life support, exercise, and habitation equipment evaluations.
9. **TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE**
   Lunar free return trajectory initiated with European service module.
10. **OUTBOUND TRANSIT TO MOON**
    4 days outbound transit along free return trajectory.
11. **LUNAR FLYBY**
    4,000 nmi (mean) lunar farside altitude.
12. **TRANS-EARTH RETURN**
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.
13. **CREW MODULE SEPARATION FROM SERVICE MODULE**
14. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
15. **SPLASHDOWN**
    Ship recovers astronauts and capsule.

PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE


ARTEMIS III
Landing on the Moon
1 LAUNCH
SLS and Orion lift off from Kennedy Space Center.
2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM
3 CORE STAGE MAIN ENGINE CUT OFF
With separation.
4 ENTER EARTH ORBIT
Perform the perigee raise maneuver. Systems check and solar panel adjustments.
5 TRANS LUNAR INJECTION BURN
Astronauts committed to lunar trajectory, followed by ICPS separation and disposal.
6 ORION OUTBOUND TRANSIT TO MOON
Requires several outbound trajectory burns.
7 ORION OUTBOUND POWERED FLYBY
60 nmi from the Moon.
8 NRHO INSERTION BURN
Orion performs burn to establish rendezvous point and executes rendezvous and docking.
9 LUNAR LANDING PREPARATION
Crew activates lander and prepares for departure.
10 LANDER UNDOCKING AND SEPARATION
11 LANDER ENTERS LOW LUNAR ORBIT
Descends to lunar touchdown.
12 LUNAR SURFACE EXPLORATION
Astronauts conduct week long surface mission and extra-vehicular activities.
13 ORION REMAINS IN NRHO ORBIT
During lunar surface mission.
14 LANDER ASCENDS TO LOW LUNAR ORBIT
15 LANDER PERFORMS RENDEZVOUS AND DOCKING
16 CREW RETURNS IN ORION
Orion undocks, performs orbit departure burn.
17 ORION PERFORMS RETURN POWERED FLYBY
60 nmi from the Moon.
18 FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN
Precision targeting for Earth entry.
19 CREW MODULE SEPARATION FROM SERVICE MODULE
20 ENTRY INTERFACE (EI)
Enter Earth's atmosphere.
21 SPLASHDOWN
Ship recovers astronauts and capsule
DESCEND
ASCEND
NEAR-RECTILINEAR HALO ORBIT (NRHO)
To Earth
NASA
ARTEMIS

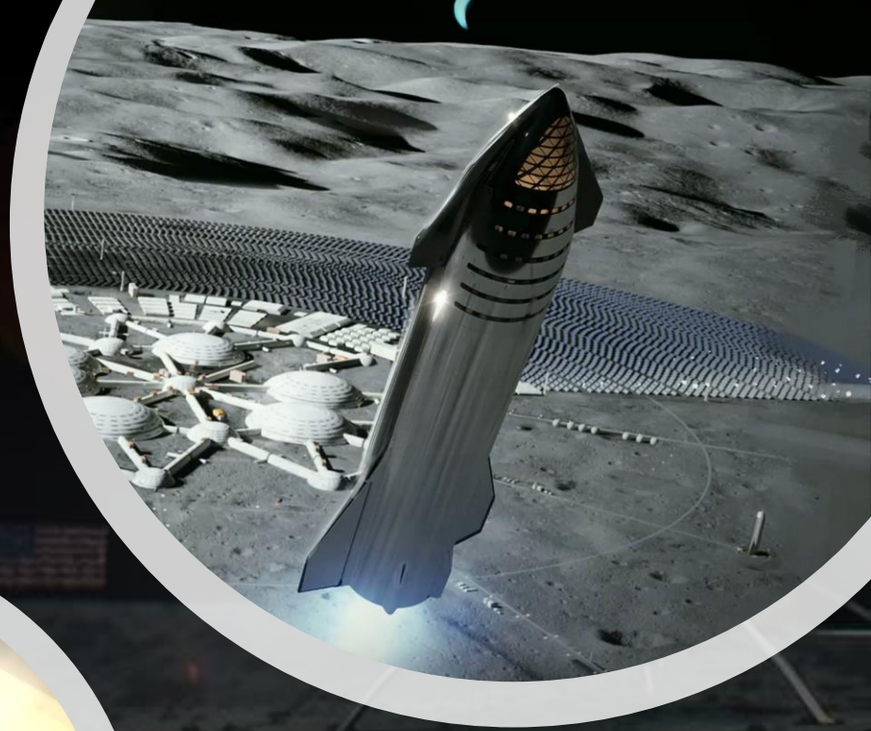
Artemis Element Comparison

Element	Environment	Gravity	Crew Presence	Science Role	Science Timing
Gateway	Both	Micro	17-24 days	ISS-like	Untended: years
HLS	Pressurized	Micro/Lunar	~4-7 days	Supply delivery	~days
Surface Habitat or Pressurized Rover	Both	Lunar	~month at ABC	In situ measurements & leave behind	Untended: months
Lunar Terrain Vehicle	Unpressurized	Lunar	~1 day	Expanded range	Untended: months
CLPS	Unpressurized	Micro/Lunar	None	Experiment Staging & leave behind	Untended: months
Orion	Pressurized	Micro/Earth	4-6 day transit	Human	~weeks



The number and variety of interfaces pose a difficult integration challenge for science operations.

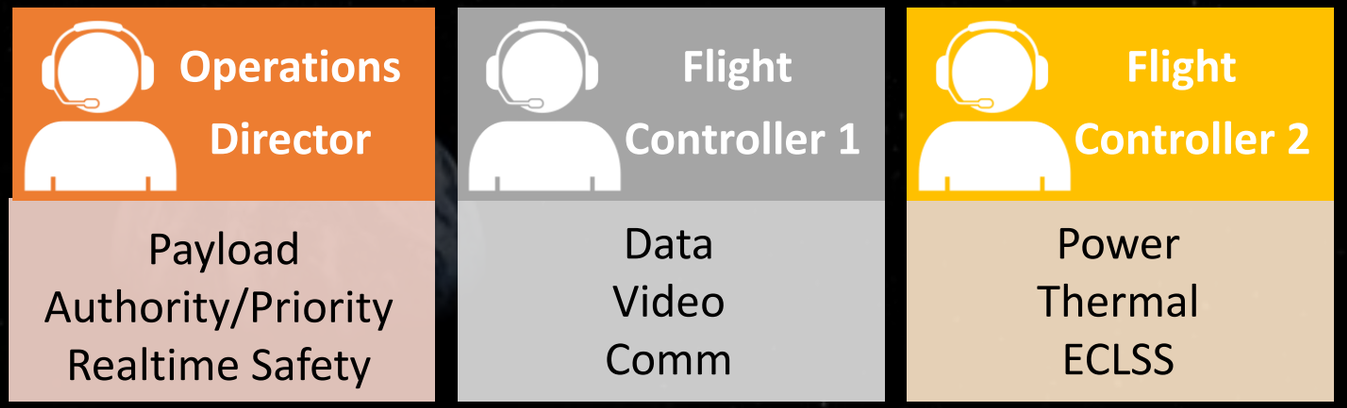
Integration Example: Volatile Sample Return



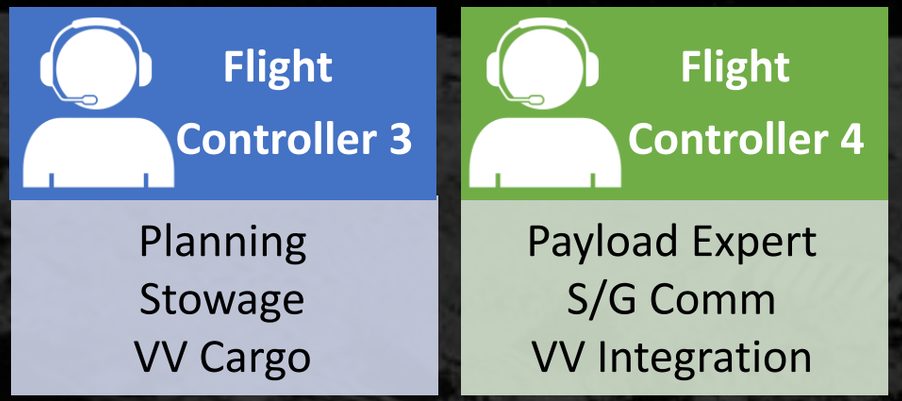
- Objectives defined by Principal Investigator
- Collected with tools developed by the extra-vehicular activity (EVA) team
- Stored on Lunar Terrain Vehicle or Surface Habitat
- Ascend in commercial HLS
- Temporarily installed with resource connections on Gateway
- Transferred to Orion for return
- Proposed solutions
  - Single integrating science ops authority
  - Establishment of science ops standards (mechanical, software, ops practices)
  - Build a model suitable for crewed missions and for sustained science operations

Integrated Artemis Flight Control Team

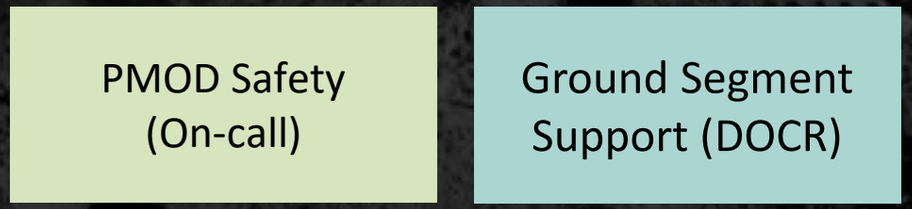
Core team members provide multi-program support throughout the entire mission through 24x7, 8x5, dynamic event, or remote support.



Core+ Team members provide multi-program increased support leading up to and during crewed stages.

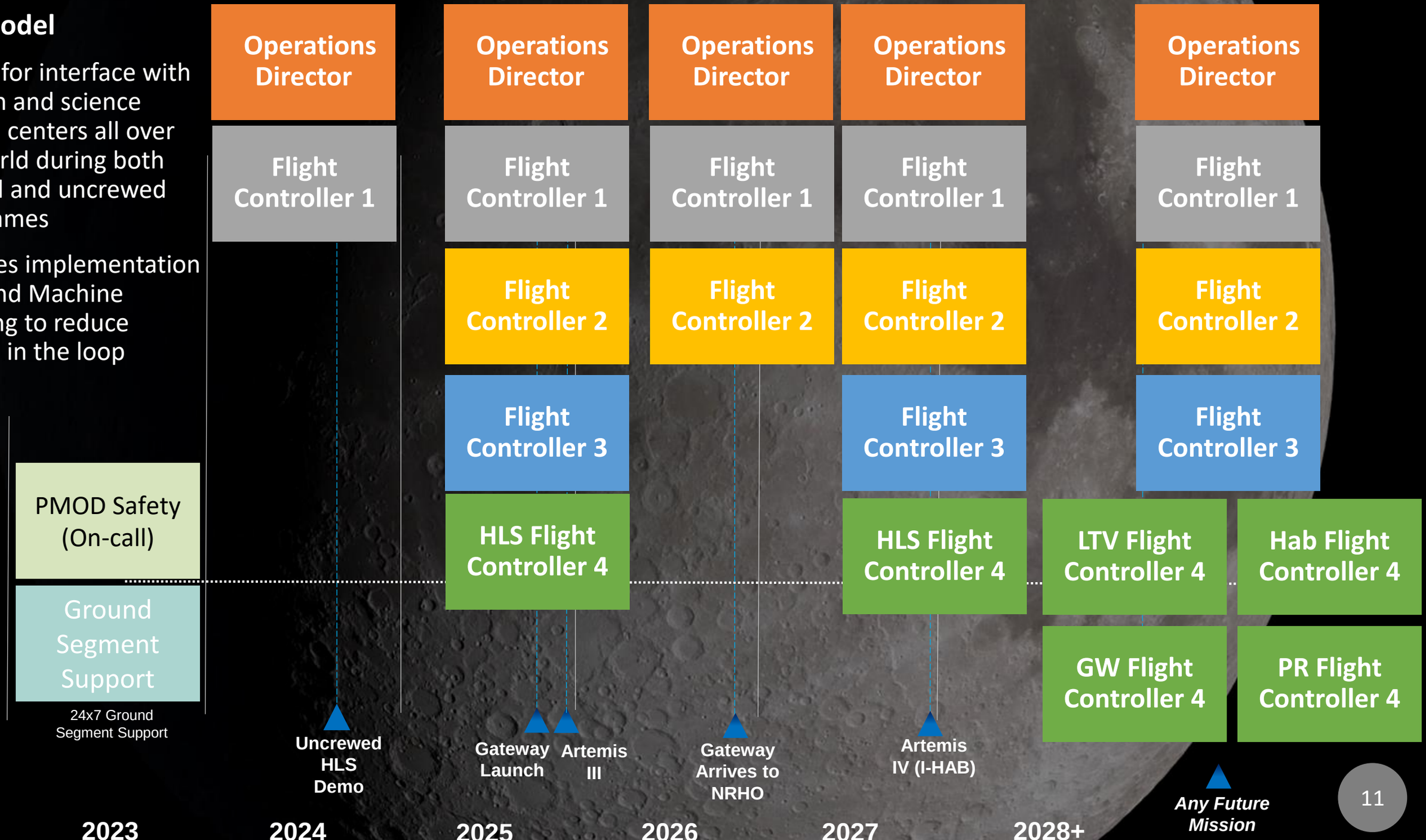


Multi-program support positions.



Core+ Model

- Allows for interface with mission and science control centers all over the world during both crewed and uncrewed timeframes
- Requires implementation of AI and Machine Learning to reduce human in the loop



Beyond Artemis

- Commercial LEO Destination (CLD) Program will help transition from government sponsored LEO environment to one sustained by commercial endeavors
- POIC will help develop science operational standards thereby ensuring a safe and robust commercial economy in LEO
  - Especially for new technologies like Smart Assistants and built in Artificial Intelligence

Summary

- Science operations have considerably increased in complexity in the last 10 years since the start of Commercial Resupply and Commercial Crew.
- POIC has played a crucial role in developing the science operations concepts and executing the operations necessary to support this new era.
- Artemis mission will introduce another wave of complexity requiring new ops concepts to create a sustained science operations environment across the multiple platforms, providers and agencies.

Thank you

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